11th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2007, Hammamet, Tunisia, 05-09 September, 2007.

EXPERIMENTAL AND NUMERICAL STUDY OF PERFORATED OPEN STEEL SECTIONS, SUBJECT TO COMPRESSION

Francesc Roure
Mª Magdalena Pastor

Department of Strength of Materials and Structural Engineering
UPC (Universitat Politècnica de Catalunya)
Diagonal 647, 0828 Barcelona
Spain

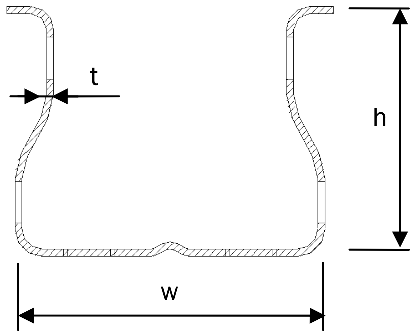
ABSTRACT
The results of several perforated steel thin-walled U-shaped sections subject to compression are presented. The ultimate strength obtained from experimental tests is compared to the one obtained from numerical simulation by finite element method.
The experimental tests were carried out according to the standard 10.2.02 of the FEM. The meshing, loading, boundary conditions for supports, geometric and material properties are introduced in the model in conformity with the experimental tests.
Tests previously carried out on short columns (l = 250÷400 mm) provided local and distortional buckling modes. The aim of this study is to analyze the behaviour of longer columns (l > 1000 mm,) which provide other critical buckling modes.
Keywords: Steel open sections**,** buckling modelling, experimental tests, finite elements.

1. INTRODUCTION
In pallet racking systems it is habitual to use for the uprights open cold formed thin steel sections. The failure load under compression for this type of section is always determined by instabilities.
In an earlier communication [1] we have reported an experimental and numerical analysis of short specimens of this type of section, under compression ("short column"). For them the position of the effective centre of gravity, the effective area and the ultimate load have been determined.
In the present communication we explain the results of the same type of analysis, applied to the same sections, first using short columns (length between 250 and 400 mm), and then using longer specimens (length between 1000 and 1200 mm), to validate the simulation method for the different types of instabilities: local, distortional and global buckling.

2. SECTIONS ANALYZED
The dimensions of the sections analyzed are resumed in the table of fig.1.

3. SHORT COLUMNS TESTS

3.1 Experimental Tests
The experimental layout for testing the short columns is shown in fig.2. At both ends of the specimen a specially designed base plate allows to apply the axial compression load through a precisely determined point (a steel ball is used), and to vary the position of this point along the axis of



Column	w (mm)	h (mm)	t (mm)
A	49,0	54,0	1,5
B	76,2	63,2	1,8
C	79,5	63,0	1,8
D	100,6	69,0	1,8
E	102,0	123,2	2,5

Figure 1. Dimensions of the sections analyzed

symmetry of the section. In a first stage the position of the effective centre of gravity is determined, by varying the position of the load application point and finding the maximum failure load. Then the failure load is determined as the medium of three tests in this position. The usual failure modes are local buckling of the web or the flanges, or distortional buckling.

3.2 Numerical simulation

A finite element model has been created, using ANSYS. Shell 181 element has been used, and the boundary conditions introduced reproduce those of the experimental setup (see fig.3). The methodology used here has been presented by our group in earlier papers [2] and [3]. In a first stage, by means of a modal linear analysis, the eigen modes are determined. Then the displacements of the first eigen mode are introduced as initial displacements to perform a non linear analysis (elastic-plastic response of the material and large displacements) to determinate the failure load and failure mode. The failure modes obtained by FEM coincide with those obtained experimentally. In the table of fig. 6 the failure loads obtained with both methods are compared.

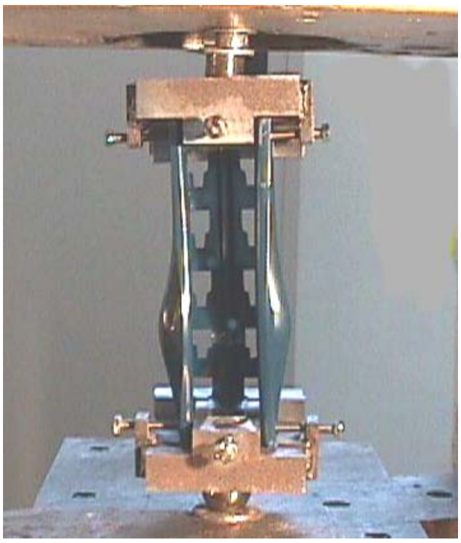


Figure 2. Experimental testing of a short column

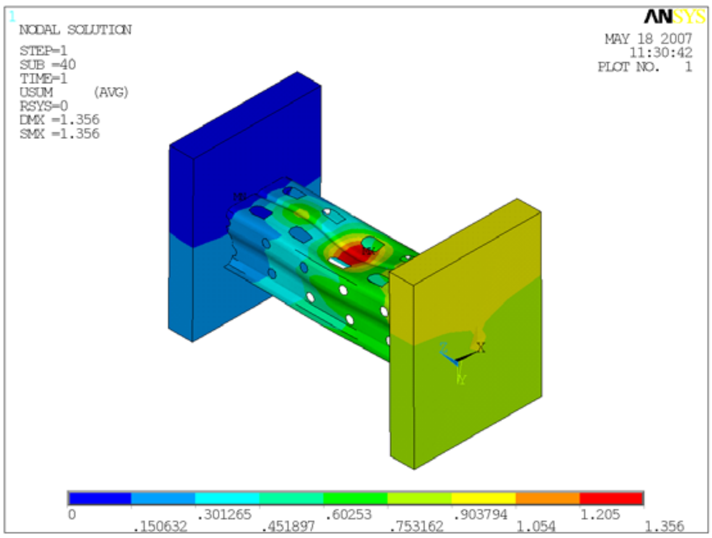


Figure 3. Numerical simulation: local buckling of the web of a short column

4. LONG COLUMN TESTS

4.1 Experimental tests

The same experimental methodology has been used to test long column samples (length between 1000 and 1200 mm). The load has been applied trough the effective centre of gravity, obtained previously in 3.1. The failure modes here are global and distortional.

4.2 Numerical simulation

The same numerical methodology as described in 3.2 has been used now to analyze the long columns. The model reproduces also the perforations of columns analyzed (see fig.4). The number of elements necessary to build the model is about 10.000. The failure modes coincide with those obtained experimentally (see fig.5). The failure loads obtained with both methods are compared in the table of fig. 6.

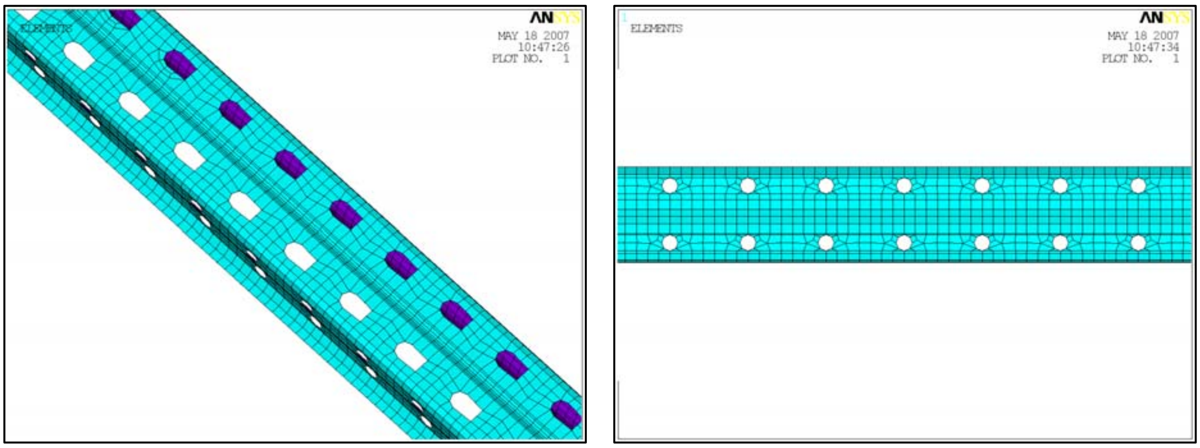


Figure 4. Details of the FE meshing in the model of a long column

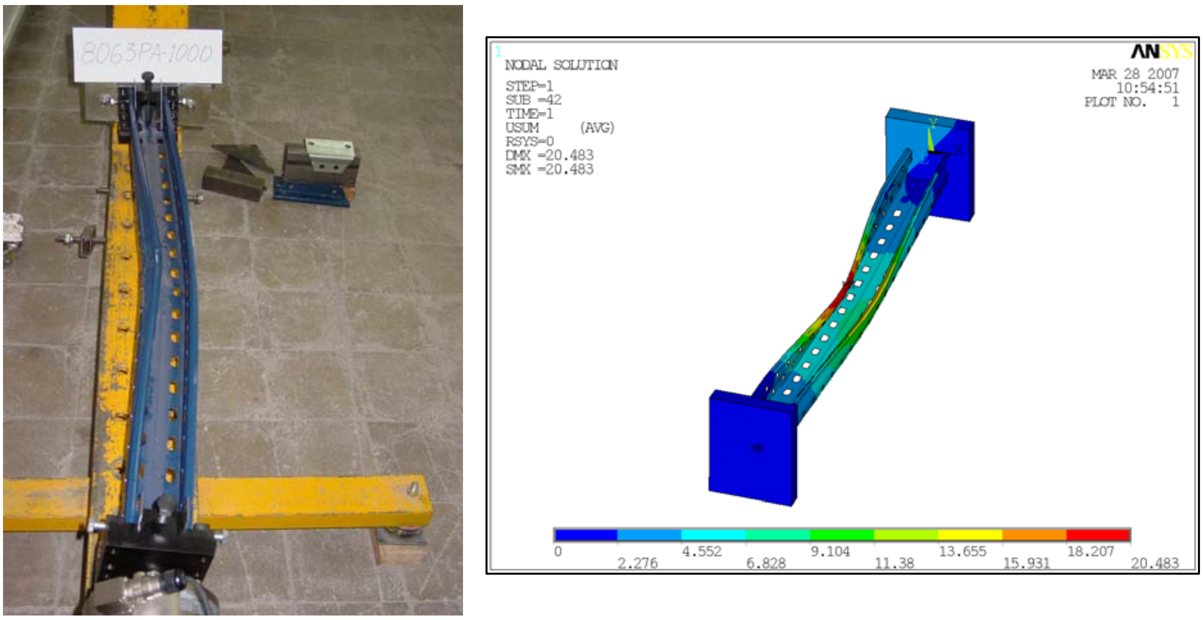


Figure 5. Experimental and numerically simulated failure of a long column, due to distortional buckling

5. ANALYSIS OF THE RESULTS

The results are resumed in the table of fig.6.

The position of the effective centre of gravity of the section, obtained in the short columns with the FEM simulation, coincides very well with the position obtained experimentally: the highest difference is 1 mm.

The failure modes obtained with the non linear FEM coincide well with the modes obtained experimentally, both in short and long columns.

The value of the failure load obtained with the numerical simulation is always lower than the value obtained experimentally, varying this difference within -0.2% and -10%.

Section	Short columns					Long columns		
	ℓ (mm)	Experimental		Numerical		ℓ (mm)	Exper.	Numer.
		G_{ef} (mm)	F_f (N)	G_{ef} (mm)	F_f (N)		F_f (N)	F_f (N)
A	250	17	63.176	18	56.826	1000	39.510	37.869
						1150	35.924	33.051
B	250	26	163.500	26,5	151.371	1200	134.279	121.733
C	250	25	118.367	26	113.722	1000	97.610	95.672
						1150	97.717	93.428
D	350	26	154.508	26	138.899	1100	147.206	134.234
E	400	58	465.594	58	457.146	1200	350.675	350.000

Figure 6. Comparison of experimental and numerical results, for short and long columns

6. CONCLUSIONS

The simulation methodology used here is a very good way to predict the position of the effective centre of gravity of open thin walled steel sections, under compression. It is also a good way to predict the mode of failure to compression due to instabilities, and to predict the value of the failure load. The predicted value of the failure load is always lower than the real one, and therefore is always in the safe side.

7. AKNOLEDGMENTS

We wish to thank the very important contribution to this work done by Eduardo Chillaron, student research fellow, responsible for running the ANSYS calculations; and the contribution of Mª Rosa Somalo, research engineer, and Juan Espada and F. Joaquim Garcia, laboratory technicians, responsible of the experimental testing.

8. REFERENCES

[1] Roure F., Casafont M., Pastor M.M., Somalo M.R.: Effective cross-sectional area of steel thin-walled U-shaped sections, obtained by different methods, 4th European Conference on Steel and Composite Structures, EUROSTEEL 2005, Maastricht, Nederland, 2005.

[2] Casafont M,: Comportamiento de perfiles perforados de chapa conformada sometidos a flexo-compresión, Doctoral Thesis, Universitat Politècnica de Catalunya (UPC), Barcelona, 2003.

[3] Casafont, M., Marimon F., Roure F.: Compression strength of perforated cold-formed steel columns, The third International Conference on Advances in Structural Engineering and Mechanics, Seoul, Korea, 2004.